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CONTENTS.



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## *THE PROGRESS OF PHYSICS IN THE NINETEENTH CENTURY.*[1]

### I.

*Mr. President, Ladies and Gentlemen:* You have honored me by requesting at my hands an account of the advances made in physics during the nineteenth century. I have endeavored, in so far as I have been able, to meet the grave responsibilities implied in your invitation; yet had I but thought of the overwhelmingly vast territory to be surveyed, I well might have hesitated to embark on so hazardous an undertaking. To mention merely the *names* of men whose efforts are linked with splendid accomplishments in the history of modern physics would far exceed the time allotted to this address. To bear solely on certain subjects, those for instance with which I am more familiar, would be to develop an unsymmetrical picture. As this is to be avoided, it will be necessary to present a straightforward compilation of all work above a certain somewhat vague and arbitrary lower limit of importance. Physics is, as a rule, making vigorous though partial progress along independent parallel lines of investigation, a discrimination between which is not possible until some cataclysm in the history of thought ushers in a new era. It will be essential to abstain from entering into either explanation or criticism and to assume that all present are familiar with the details of the subjects to be treated. I can neither popularize nor can I endeavor to entertain, except in so far as a rapid review of the glorious conquests of the century may be stimulating.

In spite of all this simplicity of aim, there is bound to be distortion. In any brief account, the men working at the beginning of the century, when investigations were few and the principles evolved necessarily fundamental, will be given greater consideration than equally able and abler

[1] Paper read at the International Congress in St. Louis.

investigations near the close, when workers (let us be thankful) were many, and the subjects lengthening into detail. Again, the higher order of genius will usually be additionally exalted at the expense of the less gifted thinker. I can but regret that these are the inevitable limitations of the cursory treatment prescribed. As time rolls on the greatest names more and more fully absorb the activity of a whole epoch.

METROLOGY.

Finally, it will hardly be possible to consider the great advances made in physics except on the theoretical side. Of renowned experimental researches, in particular of the investigations of the constants of nature to a degree of ever increasing accuracy, it is not practicable to give any adequate account. Indeed, the refinement and precision now demanded have placed many subjects beyond the reach of individual experimental research, and have culminated in the establishment of the great national or international laboratories of investigation at Sèvres (1872), at Berlin (1887, 1890), at London (1900), at Washington (1901). The introduction of uniform international units in cases of the arts and sciences of more recent development is gradually, but inexorably, urging the same advantages on all. Finally, the access to adequate instruments of research has everywhere become an easier possibility for those duly qualified, and the institutions and academies which are systematically undertaking the distribution of the means of reasearch are continually increasing in strength and in number.

CLASSIFICATION.

In the present paper it will be advisable to follow the usual procedure in physics, taking in order the advances made in dynamics, acoustics, heat, light and electricity. The plan pursued will, therefore, specifically consider the progress in elastics, crystallography, capillarity, solution, diffusion, dynamics, viscosity, hydrodynamics, acoustics; in thermometry, calorimetry, thermodynamics, kinetic theory, thermal radiation; in geometric optics, dispersion, photometry, fluorescence, photochemistry, interference, diffraction, polarization, optical media; in electrostatics, Volta contacts, Seebeck contacts, electrolysis, electric current, magnetism, electromagnetism, electrodynamics, induction, electric oscillation, electric field, radioactivity.

Surely this is too extensive a field for any one man! Few who are not physicists realize that each of these divisions has a splendid and voluminous history of development, its own heroes, its sublime classics often culled from the activity of several hundred years. I repeat that few understand the unmitigatedly fundamental character, the scope, the vast and profound intellectual possessions, of pure physics; few think of it as the one science into which all other sciences must ultimately converge —or a separate representation would have been given to most of the great divisions which I have named.

Hence even if the literary references may be given in print with some fullness, it is impossible to refer verbally to more than the chief actors and quite impossible to delineate sharply the real significance and the relations of what has been done. Moreover, the dates will in most instances have to be omitted from the reading. It has been my aim, however, to collect the greater papers in the history of physics, and the suggestion is implied that science would gain if by some august tribunal researches of commanding importance were formally canonized for the benefit of posterity.

ELASTICS.

To begin with elasticity, whose development has been of such marked influ-

ence throughout the whole of physics, we note that the theory is virtually a creation of the nineteenth century. Antedating Thomas Young, who in 1807 gave to the subject the useful conception of a modulus, and who seems to have definitely recognized the shear, there were merely the experimental contribution of Galileo (1638), Hooke (1660), Mariotte (1680), the elastic curve of J. Bernoulli (1705), the elementary treatment of vibrating bars of Euler and Bernoulli (1742), and an attempted analysis of flexure and torsion by Coulomb (1776).

The establishment of a theory of elasticity on broad lines begins almost at a bound with Navier (1821), reasoning from a molecular hypothesis to the equation of elastic displacement and of elastic potential energy (1822–1827); yet this startling advance was destined to be soon discredited, in the light of the brilliant generalizations of Cauchy (1827). To him we owe the six component stresses and the six component strains, the stress quadric and the strain quadric, the reduction of the components to three principal stresses and three principal strains, the ellipsoids and other of the indispensable conceptions of the present day. Cauchy reached his equations both by the molecular hypothesis and by an analysis of the oblique stress across an interface—methods which predicate fifteen constants of elasticity in the most general case, reducing to but one in the case of isotropy. Cotemporaneous with Cauchy's results are certain independent researches by Lamé and Clapeyron (1828) and by Poisson (1829).

Another independent and fundamental method in elastics was introduced by Green (1837), who took as his point of departure the potential energy of a conservative system in connection with the Lagrangian principle of virtual displacements. This method, which has been fruitful in the hands of Kelvin (1856), of Kirchhoff (1876), of Neumann (1885), leads to equations with twenty-one constants for the æolotropic medium reducing to two in the simplest case.

The wave motion in an isotropic medium was first deduced by Poisson in 1828, showing the occurrence of longitudinal and transverse waves of different velocities; the general problem of wave motion in æolotropic media, though treated by Green (1842), was attacked with requisite power by Blanchet (1840–1842) and by Christoffel (1877).

Poisson also treated the case of radial vibrations of a sphere (1828), a problem which, without this restriction, awaited the solutions of Jaerisch (1879) and of Lamb (1882). The theory of the free vibrations of solids, however, is a generalization due to Clebsch (1857–58, 'Vorlesungen,' 1862).

Elasticity received a final phenomenal advance through the long continued labors of de St. Venant (1839–55), which in the course of his editions of the work of Moigno, of Navier (1863), and of Clebsch (1864), effectually overhauled the whole subject. He was the first to adequately assert the fundamental importance of the shear. The profound researches of de St. Venant on the torsion of prisms and on the flexure of prisms appeared in their complete form in 1855 and 1856. In both cases the right sections of the stressed solids are shown to be curved and the curvature is succinctly specified; in the former Coulomb's inadequate torsion formula is superseded and in the latter flexural stress is reduced to a transverse force and a couple. But these mere statements convey no impression of the magnitude of the work.

Among other notable creations with a special bearing on the theory of elasticity there is only time to mention the invention and application of curvilinear coordinates by Lamé (1852); the reciprocal theorem

of Betti (1872), applied by Cerruti (1882) to solids with a plane boundary—problems to which Lamé and Clapeyron (1828) and Boussinesq (1879–85) contributed by other methods; the case of the strained sphere studied by Lamé (1854) and others; Kirchhoff's flexed plate (1850); Rayleigh's treatment of the oscillations of systems of finite freedom (1873); the thermo-elastic equations of Duhamel (1838), of F. Neumann (1841), of Kelvin (1878); Kelvin's analogy of the torsion of prisms with the supposed rotation of an incompressible fluid within (1878); his splendid investigations (1863) of the dynamics of elastic spheroids and the geophysical applications to which they were put.

Finally, the battle royal of the molecular school following Navier, Poisson, Cauchy and championed by de St. Venant, with the disciples of Green headed by Kelvin and Kirchhoff—the struggle of the fifteen constants with the twenty-one constants, in other words—seems to have temporarily subsided with a victory for the latter through the researches of Voigt (1887–89).

### CRYSTALLOGRAPHY.

Theoretical crystallography, approached by Steno (1669), but formally founded by Haüy (1781, 'Traité,' 1801), has limited its development during the century to systematic classifications of form. Thus the thirty-two type sets of Hessel (1830) and of Bravais (1850) have expanded into the more extensive point series involving 230 types due to Jordan (1868), Sohncke (1876), Federow (1890) and Schoenfliess (1891). Physical theories of crystalline form have scarcely been unfolded.

### CAPILLARITY.

Capillarity antedated the century in little more than the provisional, though brilliant, treatment due to Clairaut (1743). The theory arose in almost its present state of perfection in the great memoir of Laplace (1805), one of the most beautiful examples of the Newton-Boscovichian (1758) molecular dynamics. Capillary pressure was here shown to vary with the principal radii of curvature of the exposed surface, in an equation involving two constants, one dependent on the liquid only, the other doubly specific for the bodies in contact. Integrations for special conditions include the cases of tubes, plates, drops, contact angle, and similar instances. Gauss (1829), dissatisfied with Laplace's method, virtually reproduced the whole theory from a new basis, avoiding molecular forces in favor of Lagrangian displacements, while Poisson (1831) obtained Laplace's equations by actually accentuating the molecular hypothesis; but his demonstration has since been discredited. Young in 1805 explained capillary phenomena by postulating a constant surface tension, a method which has since been popularized by Maxwell ('Heat,' 1872).

With these magnificent theories propounded for guidance at the very threshold of the century, one is prepared to anticipate the wealth of experimental and of detailed theoretical research which has been devoted to capillarity. Among these the fascinating monograph of Plateau (1873), in which the consequences of theory are tested by the behavior both of liquid lamellæ and by suspended masses, Savart's (1833), and particularly Rayleigh's, researches with jets (1879–83), Kelvin's ripples (1871), may be cited as typical. Of peculiar importance, quite apart from its meteorological bearing, is Kelvin's deduction (1870) of the interdependence of surface tension and vapor pressure when varying with the curvature of a droplet.

### DIFFUSION.

Diffusion was formally introduced into physics by Graham (1850). Fick (1855),

appreciating the analogy of diffusion and heat conduction, placed the phenomenon on a satisfactory theoretical basis, and Fick's law has since been rigorously tested, in particular by H. F. Weber (1879).

The development of diffusion from a physical point of view followed Pfeffer's discovery (1877) of osmotic pressure, soon after to be interpreted by vant' Hoff (1887) in terms of Boyle's and Avogadro's laws. A molecular theory of diffusion was thereupon given by Nernst (1887).

DYNAMICS.

In pure dynamics the nineteenth century inherited from the eighteenth that unrivaled feat of reasoning called by Lagrange the 'Mécanique Analytique' (1788), and the great master was present as far as 1813 to point out its resources and to watch over the legitimacy of its applications. Throughout the whole century each new advance has but vindicated the preeminent power and safety of its methods. It triumphed with Maxwell (1864), when he deduced the concealed kinetics of the electromagnetic field, and with Gibbs (1876–78), when he adapted it to the equilibrium of chemical systems. It will triumph again in the electromagnetic dynamics of the future.

Naturally there were reactions against the tyranny of the method of 'liaisons.' The most outspoken of these, propounded under the protection of Laplace himself, was the celebrated 'mécanique physique' of Poisson (1828), an accentuation of Boscovich's (1758) dynamics, which permeates the work of Navier, Cauchy, de St. Venant, Boussinesq, even Fresnel, Ampère and a host of others. Cauchy in particular spent much time to reconcile the molecular method with the Lagrangian abstractions. But Poisson's method, though sustained by such splendid genius, has, nevertheless, on more than one occasion—in capillarity, in elastics—shown itself to be untrustworthy. It was rudely shaken when, with the rise of modern electricity, the influence of the medium was more and more pushed to the front.

Another complete reconstruction of dynamics is due to Thomson and Tait (1867), in their endeavor to gain clearness and uniformity of design, by referring the whole subject logically back to Newton. This great work is the first to make systematic use of the doctrine of the conservation of energy.

Finally, Hertz (1894), imbued with the general trend of cotemporaneous thought, made a powerful effort to exclude force and potential energy from dynamics altogether—postulating a universe of concealed motions such as Helmholtz (1884) had treated in his theory of cyclic systems, and Kelvin had conceived in his adynamic gyrostatic ether (1890). In fact the introduction of concealed systems and of ordered molecular motions by Helmholtz and Boltzmann has proved most potent in justifying the Lagrangian dynamics in its application to the actual motions of nature.

The specific contributions of the first rank which dynamics owes to the last century, engrossed as it was with the applications of the subject, or with its mathematical difficulties, are not numerous. In chronological order we recall naturally the statics (1804) and the rotational dynamics (1834) of Poinsot, all in their geometrical character so surprisingly distinct from the cotemporary dynamics of Lagrange and Laplace. We further recall Gauss's principle of least constraint (1829), but little used, though often in its applications superior to the method of displacement; Hamilton's principle of varying action (1834) and his characteristic function (1834, 1835), the former obtainable by an easy transition from D'Alembert's prin-

ciple and by contrast with Gauss's principle, of such exceptional utility in the development of modern physics; finally the development of the Leibnitzian doctrine of work and *vis viva* into the law of the conservation of energy, which more than any other principle has consciously pervaded the progress of the nineteenth century. Clausius's theorem of the 'Virial' (1870) and Jacobi's (1866) contributions should be added among others.

The potential, though contained explicitly in the writings of Lagrange (1777), may well be claimed by the last century. The differential equation underlying the doctrine had already been given by Laplace in 1782, but it was subsequently to be completed by Poisson (1827). Gauss (1813, 1839) contributed his invaluable theorems relative to the surface integrals and force flux, and Stokes (1854) his equally important relation of the line and the surface integral. Legendre (published 1785) and Laplace (1782) were the first to apply spherical harmonics in expansions. The detailed development of volume surface and line potential has enlisted many of the ablest writers, among whom Chasles (1837, 1839, 1842), Helmholtz (1853), C. Neumann (1877, 1880), Lejeune-Dirichlet (1876), Murphy (1833) and others are prominent.

The gradual growth of the doctrine of the potential would have been accelerated, had not science to its own loss overlooked the famous essay of Green (1828) in which many of the important theorems were anticipated, and of which Green's theorem and Green's function are to-day familiar reminders.

Recent dynamists incline to the uses of the methods of modern geometry and to the vector calculus with continually increasing favor. Noteworthy progress was first made in this direction by Moebius (1837–43, 'Statik,' 1838), but the power of these methods to be fully appreciated required the invention of the 'Ausdehnungslehre,' by Grassmann (1844), and of 'quaternions,' by Hamilton (1853).

Finally the profound investigations of Sir Robert Ball (1871, et seq., 'Treatise') on the theory of screws with its immediate dynamical applications, though as yet but little cultivated except by the author, must be reckoned among the promising heritages of the twentieth century.

On the experimental side it is possible to refer only to researches of a strikingly original character like Foucault's pendulum (1851) and Fizeau's gyrostat; or like Boys's (1887, et seq.) remarkable quartz-fiber torsion-balance, by which the Newtonian constant of gravitation and the mean density of the earth originally determined by Maskelyne (1775–78) and by Cavendish (1798) were evaluated with a precision probably superior to that of the other recent measurements, the pendulum work of Airy (1856) and Wilsing (1885–87), or the balance methods of Jolly (1881), König and Richarz (1884). Extensive transcontinental gravitational surveys like that of Mendenhall (1895) have but begun.

### HYDRODYNAMICS.

The theory of the equilibrium of liquids was well understood prior to the century even in the case of rotating fluids, thanks to the labors of Maclaurin (1742), Clairaut (1743) and Lagrange (1788). The generalizations of Jacobi (1834) contributed the triaxial ellipsoid of revolution and the case has been extended to two rotating attracting masses by Poincaré (1885) and Darwin (1887). The astonishing revelations contained in the recent work of Poincaré are particularly noteworthy.

Unlike elastics, theoretical hydrodynamics passed into the nineteenth century in a relatively well-developed state. Both types of the Eulerian equations of motion

(1755, 1759) had left the hands of Lagrange (1788) in their present form. In relatively recent time, H. Weber (1868) transformed them in a way combining certain advantages of both, and another transformation was undertaken by Clebsch (1859). Hankel (1861) modified the equation of continuity, and Svanberg and Edlund (1847) the surface conditions.

Helmholtz in his epoch-making paper of 1858 divided the subject into those classes of motion (flow in tubes, streams, jets, waves) for which a velocity potential exists and the vortex motions for which it does not exist. This classification was carried even into higher orders of motion by Craig and by Rowland (1881). For cases with a velocity potential, much progress has been made during the century in the treatment of waves, of discontinuous fluid motion, and in the dynamics of solids suspended in frictionless liquids. Kelland (1844), Scott Russel (1844) and Green (1837) dealt with the motion of progressive waves in relatively shallow vessels, Gerster (1804) and Rankine (1863) with progressive waves in deep water, while Stokes (1846, 1847, 1880) after digesting the contemporaneous advances in hydrodynamics, brought his powerful mind to bear on most of the outstanding difficulties. Kelvin introduced the case of ripples (1871), afterwards treated by Rayleigh (1883). The solitary wave of Russel occupied Boussinesq (1872, 1882), Rayleigh (1876) and others; group waves were treated by Reynolds (1877) and Rayleigh (1879). Finally the theory of stationary waves received extended attention in the writings of de St. Venant (1871), Kirchhoff (1879) and Greenhill (1887). Early experimental guidance was given by the classic researches of C. H. and W. Weber (1825).

The occurrence of discontinuous variation of velocity within the liquid was first fully appreciated by Helmholtz (1868), later by Kirchhoff (1869), Rayleigh (1876), Voigt (1885) and others. It lends itself well to conformal representations.

The motions of solids within a liquid have fascinated many investigators and it is chiefly in connection with this subject that the method of sources and sinks was developed by English mathematicians, following Kelvin's method (1856) for the flow of heat. The problem of the sphere was solved more or less completely by Poisson (1832), Stokes (1843), Dirichlet (1852); the problem of the ellipsoid by Green (1833), Clebsch (1858), generalized by Kirchhoff (1869). Rankine treated the translatory motion of cylinders and ellipsoids in a way bearing on the resistance of ships. Stokes (1843) and Kirchhoff entertain the question of more than one body. The motion of rings has occupied Kirchhoff (1869), Boltzmann (1871), Kelvin (1871), Bjerknes (1879) and others. The results of C. A. Bjerknes (1868) on the fields of hydrodynamic force surrounding spheres, pulsating or oscillating, in translatory or rotational motion accentuate the remarkable similarity of these fields with the corresponding cases in electricity and magnetism and have been edited in a unique monograph (1900) by his son. In a special category belong certain powerful researches with a practical bearing, such as the modern treatment of ballistics by Greenhill and of the ship propeller of Ressel (1826), summarized by Gerlach (1885, 1886).

The numerous contributions of Kelvin (1888, 1889) in particular have thrown new light on the difficult but exceedingly important question of the stability of fluid motion.

The century, moreover, has extended the working theory of the tides due to Newton (1687) and Laplace (1774), through the labors of Airy, Kelvin and Darwin.

Finally the forbidding subject of vortex motion was gradually approached more and more fully by Lagrange, Cauchy (1815, 1827), Svanberg (1839), Stokes (1845); but the epoch-making integrations of the differential equations together with singularly clear-cut interpretations of the whole subject are due to Helmholtz (1858). Kelvin (1867, 1883) soon recognized the importance of Helmholtz's work and extended it, and further advance came in particular from J. J. Thomson (1883) and Beltrami (1875). The conditions of stability in vortex motion were considered by Kelvin (1880), Lamb (1878), J. J. Thomson and others, and the cases of one or more columnar vortices, of cylindrical vortex sheets, of one or more vortex rings simple or linked, have all yielded to treatment.

The indestructibility of vortex motion in a frictionless fluid, its open structure, the occurrence of reciprocal forces, were compared by Kelvin (1867) with the essential properties of the atom. Others like Fitzgerald in his cobwebbed ether and Hicks (1885) in his vortex sponge have found in the properties of vortices a clue to the possible structure of the ether. Yet it has not been possible to deduce the principles of dynamics from the vortex hypothesis, neither is the property which typifies the mass of an atom clearly discernible. Kelvin invokes the corpuscular hypothesis of Lesage (1818).

### VISCOSITY.

The development of viscous flow is largely on the experimental side, particularly for solids, where Weber (1835), Kohlrausch (1863, et seq.) and others have worked out the main laws. Stokes (1845) deduced the full equations for liquids. Poiseiulle's law (1847), the motion of small solids in viscous liquids, of vibrating plates and other important special cases, has yielded to treatment. The coefficients of viscosity defined by Poisson (1831), Maxwell (1868), Hagenbach (1860), O. E. Meyer (1863), are exhaustively investigated for gases and for liquids. Maxwell (1877) has given the most suggestive and Boltzmann (1876) the most carefully formulated theory for solids, but the investigation of absolute data has but begun. The difficulty of reconciling viscous flow with Lagrange's dynamics seems first to have been adjusted by Navier.

### AEROMECHANICS.

Aerostatics is indissolubly linked with thermodynamics. Aerodynamics has not marked out for itself any very definite line of progress. Though the resistance of oblique planes has engaged the attention of Rayleigh, it is chiefly on the experimental side that the subject has been enriched, as, for instance, by the labors of Langley (1891) and Lilienthal. Langley (1897) has, indeed, constructed a steam propelled aeroplane which flew successfully; but man himself has not yet flown.

Moreover, the meteorological applications of aerodynamics contained in the profound researches of Guldberg and Mohn (1877), Ferrel (1877), Oberbeck (1882, 1886), Helmholtz (1888, 1889) and others, as well as in such investigations as Sprung's (1880) on the inertia path, are as yet rather qualitative in their bearing on the actual motions of the atmosphere. The marked progress of meteorology is on the observational side.

### ACOUSTICS.

Early in the century the velocity of sound given in a famous equation of Newton was corrected to agree with observation by Laplace (1816).

The great problems in acoustics are addressed in part to the elastician, in part to the physiologist. In the former case the work of Rayleigh (1877) has described the present stage of development, interpreting

and enriching almost every part discussed. In the latter case Helmholtz (1863) has devoted his immense powers to a like purpose and with like success. König has been prominently concerned with the construction of accurate acoustic apparatus.

It is interesting to note that the differential equation representing the vibration of strings was the first to be integrated; that it passed from D'Alembert (1747) successively to Euler (1779), Bernoulli (1753) and Lagrange (1759). With the introduction of Fourier's series (1807) and of spherical harmonics at the very beginning of the century, D'Alembert's and the other corresponding equations in acoustics readily yielded to rigorous analysis. Rayleigh's first six chapters summarize the results for one and for two degrees of freedom.

Flexural vibration in rods, membranes and plates become prominent in the unique investigations of Chladni (1787, 1796, 'Akustik,' 1802). The behavior of vibrating rods has been developed by Euler (1779), Cauchy (1827), Poisson (1833), Strehlke (1833), Lissajous (1833), Seebeck (1849), and is summarized in the seventh and eighth chapters of Rayleigh's book. The transverse vibration of membranes engaged the attention of Poisson (1829). Round membranes were rigorously treated by Kirchhoff (1850) and by Clebsch (1862); elliptic membranes by Mathieu (1868). The problem of vibrating plates presents formidable difficulties resulting not only from the edge conditions, but from the underlying differential equation of the fourth degree due to Sophie Germain (1810) and to Lagrange (1811). The solutions have taxed the powers of Poisson (1812, 1829), Cauchy (1829), Kirchhoff (1850), Boussinesq (1871–79) and others. For the circular plate Kirchhoff gave the complete theory. Rayleigh systematized the results for the quadratic plate and the general account makes up his ninth and tenth chapters.

Longitudinal vibrations which are of particular importance in case of the organ pipe, were considered in succession by Poisson (1817), Hopkins (1838), Quet (1855); but Helmholtz in his famous paper of 1860 gave the first adequate theory of the open organ pipe, involving viscosity. Further extension was then added by Kirchhoff (1868), and by Rayleigh (1870, et seq.), including particularly powerful analysis of resonance. The subject in its entirety, including the allied treatment of the resonator, completes the second volume of Rayleigh's 'Sound.'

On the other hand, the whole subject of tone quality, of combination and difference tones, of speech, of harmony, in its physical, physiological and esthetic relations, has been reconstructed, using all the work of earlier investigators by Helmholtz (1862), in his masterly 'Tonempfindungen.' With rare skill and devotion König contributed a wealth of siren-like experimental appurtenances.

Acousticians have been fertile in devising ingenious methods and apparatus, among which the tuning fork with resonator of Marloye, the siren of Cagniard de le Tour (1819), the Lissajous curves (1857), the stroboscope of Plateau (1832), the manometric flames of König (1862, 1872), the dust methods of Chladni (1787) and of Kundt (1865–68), Melde's vibrating strings (1860, 1864), the phonograph of Edison and of Bell (1877), are among the more famous.

### HEAT: THERMOMETRY.

The invention of the air thermometer dates back at least to Amontons (1699), but it was not until Rudberg (1837), and more thoroughly Regnault (1841, et seq.) and Magnus (1842) had completed their work on the thermal expansion and compressi-

bility of air, that air thermometry became adequately rigorous. On the theoretical side Clapeyron (1834), Helmholtz (1847), Joule (1848), had in various ways proposed the use of the Carnot function (1894) for temperature measurement, but the subject was finally disposed of by Kelvin (1849, et seq.) in his series of papers on temperature and temperature measurement.

Practical thermometry gained much from the measurement of the expansion of mercury by Dulong and Petit (1818), repeated by Regnault. It also profited by the determination of the viscous behavior of glass, due to Pernet (1876) and others, but more from the elimination of these errors by the invention of the Jena glass. It is significant to note that the broad question of thermal expansion has yet no adequate equation, though much has been done experimentally for fluids by the magnificent work of Amagat (1869, 1873, et seq.).

### HEAT CONDUCTION.

The subject of heat conduction from a theoretical point of view was virtually created by the great memoir of Fourier (1822), which shed its first light here, but subsequently illumined almost the whole of physics. The treatment passed successively through the hands of many of the foremost thinkers, notably of Poisson (1835, 1837), Lamé (1836, 1839, 1843), Kelvin (1841–44) and others. With the latter (1856) the ingenious method of sources and sinks originated. The character of the conduction is now well known for continuous media, isotropic or not, bounded by the more simple geometrical forms, in particular for the sphere under all reasonable initial and surface conditions. Much attention has been given to the heat conduction of the earth, following Fourier, by Kelvin (1862, 1878), King (1893) and others.

Experimentally, Wiedemann and Franz (1853) determined the relative heat conduction of metals and showed that for simple bodies a parallel gradation exists for the cases of heat and of electrical conductivity. Noteworthy absolute methods for measuring heat conduction were devised in particular by Forbes (1842), F. Neumann (1862), Ångström (1861–64), and a lamellar method applying to fluids by H. F. Weber (1880).

### CALORIMETRY.

Practical calorimetry was virtually completed by the researches of Black in 1763. A rich harvest of experimental results, therefore, has since accrued to the subjects of specific, latent and chemical heats, due in particularly important cases to the indefatigable Regnault (1840, 1845, et seq.). Dulong and Petit (1819) discovered the remarkable fact of the approximate constancy of the atomic heats of the elements. The apparently exceptional cases were interpreted for carbon silicon and boron by H. F. Weber (1875), and for sulphur by Regnault (1840). F. Neumann (1831) extended the law to compound bodies and Joule (1844) showed that in many cases specific heat could be treated as additively related to the component specific heats.

Among recent apparatus the invention of Bunsen's ice calorimeter (1870) deserves particular mention.

### THERMODYNAMICS.

Thermodynamics, as has been stated, in a singularly fruitful way interpreted and broadened the old Leibnitzian principle of *vis viva* of 1686. Beginning with the incidental experiments of Rumford (1798) and of Davy (1799) just antedating the century, the new conception almost leaped into being when J. R. Mayer (1842, 1845)

defined and computed the mechanical equivalent of heat, and when Joule (1843, 1845, et seq.) made that series of precise and judiciously varied measurements which mark an epoch. Shortly after Helmholtz (1847), transcending the mere bounds of heat, carried the doctrine of the conservation of energy throughout the whole of physics.

Earlier in the century Carnot (1824), stimulated by the growing importance of the steam engine of Watt (1763, et seq.), which Fulton (1806) had already applied to transportation by water and which Stephenson (1829) soon after applied to transportation by land, invented the reversible thermodynamic cycle. This cycle or sequence of states of equilibrium of two bodies in mutual action is, perhaps, without a parallel in the prolific fruitfulness of its contributions to modern physics. Its continued use in fifty years of research has but sharpened its logical edge. Carnot deduced the startling doctrine of a temperature criterion for the efficiency of engines. Clapeyron (1834) then gave the geometrical method of representation universally used in thermodynamic discussions to-day, though often made more flexible by new coordinates as suggested by Gibbs (1873).

To bring the ideas of Carnot into harmony with the first law of thermodynamics it is necessary to define the value of a transformation, and this was the great work of Clausius (1850), followed very closely by Kelvin (1851) and more hypothetically by Rankine (1851). The latter's broad treatment of energetics (1855) antedates many recent discussions. As early as 1858 Kirchhoff investigated the solution of solids and of gases thermodynamically, introducing at the same time an original method of treatment.

The second law was not generally accepted without grave misgiving. Clausius, indeed, succeeded in surmounting most of the objections, even those contained in theoretically delicate problems associated with radiation. Nevertheless, the confusion raised by the invocation of Maxwell's 'demon' has never quite been calmed; and while Boltzmann (1877, 1878) refers to the second law as a case of probability, Helmholtz (1882) admits that the law is an expression of our inability to deal with the individual atom. Irreversible processes as yet lie quite beyond the pale of thermodynamics. For these the famous inequality of Clausius is the only refuge. The value of an uncompensated transformation is always positive.

The invention of mechanical systems which more or less fully conform to the second law has not been infrequent. Ideas of this nature have been put forward by Boltzmann (1866, 1872), by Clausius (1870, 1871) and more powerfully by Helmholtz (1884) in his theory of cyclic systems, which in a measure suggested the hidden mechanism at the root of Hertz's dynamics. Gibbs's (1902) elementary principles of statistical mechanics seem, however, to contain the nearest approach to a logical justification of the second law —an approach which is more than a dynamical illustration.

The applications of the first and second laws of thermodynamics are ubiquitous. As interesting instances we may mention the conception of an ideal gas and its properties; the departure of physical gases from ideality as shown in Kelvin and Joule's plug experiment (1854, 1862); the corrected temperature scale resulting on the one hand, and the possibility of the modern liquid air refrigerator of Linde and Hampson (1895) on the other. Difficulties encountered in the liquefaction of incoercible gases by Cailletet and Pictet (1877) have vanished even from the hydrogen coercions

of Olezewski (1895) and of Dewar and Travers.

Again, the broad treatment of fusion and evaporation, beginning with James Thomson's (1849) computation of the melting point of ice under pressure, Kirchhoff's (1858) treatment of sublimation, the extensive chapter of thermo-elastics set on foot by Kelvin's (1883) equation, are further examples.

To these must be added Andrews's (1869) discovery of the continuity of the liquid and the gaseous states foreshadowed by Cagniard de la Tour (1822, 1823); the deep insight into the laws of physical gases furnished by the experimental prowess of Amagat (1881, 1893, 1896), and the remarkably close approximation amounting almost to a prediction of the facts observed which is given by the great work of van der Waals (1873).

The further development of thermodynamics, remarkable for the breadth, not to say audacity, of its generalizations, was to take place in connection with chemical systems. The analytical power of the conception of a thermodynamic potential was recognized nearly at the same time by many thinkers: by Gibbs (1876), who discovered both the isothermal and the adiabatic potential; by Massieu (1877), independently in his 'functions characteristiques'; by Helmholtz (1882), in his 'Freie Energie'; by Duhem (1886) and by Planck (1887, 1891), in their respective thermodynamic potentials. The transformation of Lagrange's doctrine of virtual displacements of indefinitely more complicated systems than those originally contemplated, in other words the introduction of a virtual thermodynamic modification in complete analogy with the virtual displacement of the 'mecanique analytique,' marked a new possibility of research of which Gibbs made the profoundest use. Unaware of this marshaling of powerful mathematical forces, van't Hoff (1886, 1888) consummated his marvelously simple application of the second law; and from interpretations of the experiments of Pfeffer (1877) and of Raoult (1883, 1887) propounded a new theory of solution, indeed a basis for chemical physics in a form at once available for experimental investigation.

The highly generalized treatment of chemical statics by Gibbs bore early fruit in its application to Deville's phenomenon of dissociation (1857), and in succession Gibbs (1878, 1879), Duhem (1886), Planck (1887), have deduced adequate equations, while the latter in case of dilute solutions gave a theoretical basis for Guldberg and Waage's law of mass action (1879). An earlier independent treatment of dissociation is due to Horstmann (1869, 1873).

In comparison with the brilliant advance of chemical statics which followed Gibbs, the progress of chemical dynamics has been less obvious; but the outlines of the subject have, nevertheless, been succinctly drawn in a profound paper by Helmholtz (1886), followed with much skill by Duhem (1894, 1896) and Natanson (1896).

### KINETIC THEORY OF GASES.

The kinetic theory of gases at the outset, and as suggested by Herapath (1821), Joule (1851, 1857), Krönig (1856), virtually reaffirmed the classic treatise of Bernoulli (1738). Clausius in 1857–62 gave to the theory a modern aspect in his derivation of Boyle's law in its thermal relations, molecular velocity and of the ratio of translational to total energy. He also introduced the mean free path (1858). Closely after followed Maxwell (1860), adducing the law for the distribution of velocity among molecules, later critically and elaborately examined by Boltzmann (1868–81). Nevertheless, the difficulties relating to the partition of energy have not yet been sur-

mounted. The subject is still under vigorous discussion, as the papers of Burbury (1899) and others testify.

To Maxwell (1860, 1868) is due the specifically kinetic interpretation of viscosity, of diffusion, of heat conduction, subjects which also engaged further attention from Boltzmann (1872–87). Rigorous data for molecular velocity and mean free path have thus become available, and van der Waals (1873) added a final allowance for the size of the molecules.

Less satisfactory has been the exploration of the character of molecular force for which Maxwell, Boltzmann (1872, et seq.), Sutherland (1886, 1893) and others have put forward tentative investigations.

The intrinsic equation of fluids discovered and treated in the great paper of van der Waals (1873), though partaking of the character of a first approximation, has greatly promoted the coördination of most of the known facts. Corresponding states, the thermal coefficients, the vapor pressure relation, the minimum of pressure-volume products, and even molecular diameters are reasonably inferred by van der Waals from very simple premises. Many of the results have been tested by Amagat (1896).

The data for molecular diameter furnished by the kinetic theory as a whole, viz., the original values of Loschmidt (1865), of van der Waals (1873) and others, are of the same order of values as Kelvin's estimates (1883) from capillarity and contact electricity. Many converging lines of evidence show that an approximation to the truth has surely been reached.

RADIATION.

Our knowledge of the radiation of heat, diathermacy, thermocrosis, was promoted by the perfection which the thermopyle reached in the hands of Melloni (1835–53). These and other researches set at rest forever all questions relating to the identity of heat and light. The subject was, however, destined to attain a much higher order of precision with the invention of Langley's bolometer (1881). The survey of heat spectra, beginning with the laborious attempts of Herschel (1840), of E. Becquerel (1843, 1870), H. Becquerel (1883) and others, has thus culminated in the magnificent development shown in Langley's charts (1883, 1884, et seq.).

Kirchhoff's law (1860), to some extent anticipated by Stewart (1857, 1858), pervades the whole subject. The radiation of the black body, tentatively formulated in relation to temperature by Stefan (1879) and more rigorously by Boltzmann (1884), has furnished the savants of the Reichsanstalt with means for the development of a new pyrometry whose upper limit is not in sight.

Among curious inventions Crooke's radiometer (1874) and Bell's photophone may be cited. The adaptation of the former in case of high exhaustion to the actual measurement of Maxwell's (1873) light pressure by Lebedew (1901) and Nichols and Hull (1903) is of quite recent history.

The first estimate of the important constant of solar radiation at the earth was made by Pouillet (1838); but other pyrheliometric methods have since been devised by Langley (1884) and more recently by Ångström (1886, et seq.).

VELOCITY OF LIGHT.

Data for the velocity of light, verified by independent astronomical observations, were well known prior to the century; for Römer had worked as long ago as 1675, and Bradley in 1727. It remained to actually measure this enormous velocity in the laboratory, apparently an extraordinary feat, but accomplished simultaneously by Fizeau (1849) and by the aid of Wheatstone's revolving mirror (1834) by Fou-

cault (1849, 1850, 1862). Since that time precision has been given to this important constant by Cornu (1871, 1873, 1874), Forbes and Young (1882), Michelson (1878, et seq.) and Newcomb (1885). Foucault (1850), and more accurately Michelson (1884), determined the variation of velocity with the medium and wave length, thus assuring to the undulatory theory its ultimate triumph. Grave concern, however, still exists, inasmuch as Michelson and Morley (1886) by the most refined measurement, and differing from the older observations of Fizeau (1851, 1859), were unable to detect the optical effect of the relative motion of the atmosphere and the luminiferous ether predicted by theory.

Römer's observation may in some degree be considered as an anticipation of the principle first clearly stated by Döppler (1842), which has since become invaluable in spectroscopy. Estimates of the density of the luminiferous ether have been published, in particular by Kelvin (1854).

### GEOMETRIC OPTICS.

Prior to the nineteenth century geometric optics, having been mustered before Huyghens (1690), Newton (1704), Malus (1808), Lagrange (1778, 1803) and others, had naturally attained a high order of development. It was, nevertheless, remodeled by the great paper of Gauss (1841) and was thereafter generalized step by step by Listing, Möbius (1855), and particularly by Abbe (1872), postulating that in character, the cardinal elements are independent of the physical reasons by which one region is imaged in another.

So many able thinkers like Airy (1827), Maxwell (1856, et seq.), Bessel (1840, 1841), Helmholtz (1856, 1867), Ferraris (1877, 1880) and others have contributed to the furtherance of geometric optics, that definite mention is impossible. In other cases again, profound methods like those of Hamilton (1828, et seq.), Kummer (1859), do not seem to have borne correspondingly obvious fruit. The fundamental bearing of diffraction on geometric optics was first pointed out by Airy (1838), but developed by Abbe (1873) and after him by Rayleigh (1879). An adequate theory of the rainbow, due to Airy and others, is one of its picturesque accomplishments (1838).

The so-called astronomical refraction of a medium of continuously varying index, successively treated by Bouguer (1739, 1749), Simpson (1743), Bradley (1750, 1762), owes its recent refined development to Bessel (1823, 1826, 1842), Ivory (1822, 1823, et seq.), Radau (1884) and others. Tait (1883) gave much attention to the allied treatment of mirage.

In relation to instruments the conditions of aplantism were examined by Clausius (1864), by Helmholtz (1874), by Abbe (1873, et seq.), by Hockin (1884) and others, and the apochromatic lens was introduced by Abbe (1879). The microscope is still well subserved by either the Huyghens or the Ramsden (1873) eyepiece, but the objective has undergone successive stages of improvement, beginning with Lister's discovery in 1830. Amici (1840) introduced the principle of immersion; Stephenson (1878) and Abbe (1879), homogeneous immersion; and the Abbe-Zeiss apochromatic objective (1886), the outcome of the Jena-glass experiments, marks, perhaps, the high-water mark of the art for the microscope. Steinheil (1865, 1866) introduced the guiding principle for photographic objectives. Alvan Clark carried the difficult technique of telescope lens construction to a degree of astonishing excellence.

### SPECTRUM. DISPERSION.

Curiously, the acumen of Newton (1866,

1704) stopped short of the ultimate conditions of purity of spectrum. It was left to Wollaston (1802), about one hundred years later, to introduce the slit and observe the dark lines of the solar spectrum. Fraunhofer (1814, 1815, 1823) mapped them out carefully and insisted on their solar origin. Brewster (1833, 1834), who afterwards (1860) published a map of 3,000 lines, was the first to lay stress on the occurrence of absorption, believing it to be atmospheric. Forbes (1836) gave even greater definiteness to absorption by referring it to solar origin. Foucault (1849) pointed out the coincidence of the sodium lines with the D group of Fraunhofer, and discovered the reversing effect of sodium vapor. A statement of the parallelism of emission and absorption came from Ångström (1855) and with greater definiteness and ingenious experiments from Stewart (1860). Nevertheless, it was reserved to Kirchhoff and Bunsen (1860, 1861) to give the clear-cut distinctions between the continuous spectra and the characteristically fixed bright-line or dark-line spectra upon which spectrum analysis depends. Kirchhoff's law was announced in 1861 and the same year brought his map of the solar spectrum and a discussion of the chemical composition of the sun. Huggins (1864, et seq.), Ångström (1868), Thalén (1875), followed with improved observations on the distribution and wave-length of the solar lines; but the work of these and other observers was suddenly overshadowed by the marvelous possibilities of the Rowland concave grating (1882, et seq.). Rowland's maps and tables of the solar spectrum as they appeared in 1887, 1889, et seq., his summary of the elements contained in the sun (1891), each marked a definite stage of advance of the subject. Mitscherlich (1862, 1863) probably was the first to recognize the banded or channeled spectra of compound bodies. Balmer (1885) constructed a valuable equation for recognizing the distribution of single types of lines. Kayser and Runge (1887, et seq.) successfully analyzed the structure of the spectra of alkaline and other elements.

The modernized theory of the grating had been given by Rayleigh in 1874 and was extended to the concave grating by Rowland (1892, 1893) and others. A general theory of the resolving power of prismatic systems is also due to Rayleigh (1879, 1880) and another to Thollon (1881).

The work of Rowland for the visible spectrum was ably paralleled by Langley's investigations (1883, et seq.) of the infrared, dating from the invention of the bolometer (1881). Superseding the work of earlier investigators like Fizeau and Foucault (1878) and others, Langley extended the spectrum with detailed accuracy to over eight times its visible length. The solar and the lunar spectrum, the radiations of incandescent and of hot bodies, were all specified absolutely and with precision. With artificial spectra Rubens (1892, 1899) has since gone further, reaching the longest heat waves known.

A similarly remarkable extension was added for the ultra-violet by Schumann (1890, 1892), contending successfully with the gradually increasing opacity of all known media.

Experimentally the suggestion of the spectroheliograph by Lockyer (1868) and by Janssen (1868) and its brilliant achievement by Hale (1892) promise notable additions to our knowledge of solar activity.

Finally, the refractions of absorbing media have been of great importance in their bearing on theory. The peculiarities of metallic reflection were announced from his earlier experiments (1811) by Arago in 1817 and more fully investigated by Brewster (1815, 1830, 1831). F. Neumann

(1832) and MacCullagh (1837) gave sharper statements to these phenomena. Equations were advanced by Cauchy (1836, et seq.) for isotropic bodies, and later with greater detail by Rayleigh (1872), Ketteler (1875, et seq.), Drude (1887, et seq.) and others. Jamin (1847, 1848) devised the first experiments of requisite precision and found them in close agreement with Cauchy's theory. Kundt (1888) more recently investigated the refraction of metallic prisms.

Anomalous dispersion was discovered by Christiansen in 1870, and studied by Kundt (1871, et seq.). Sellmeyer's (1872) powerful and flexible theory of dispersion was extended to include absorption effects by Helmholtz (1874), with greater detail by Ketteler (1879, et seq.), and from a different point of view by Kelvin (1885). The electromagnetic theory lends itself particularly well to the same phenomena, and Kolázek (1887, 1888), Goldhammer (1892), Helmholtz (1892), Drude (1893) and others instanced its adaptation with success.

PHOTOMETRY, FLUORESCENCE, PHOTOCHEMISTRY.

The cosine law of Lambert (1760) has since been interpreted in a way satisfying modern requirements by Fourier (1817, 1824) and by Lommel (1880). Among new resources for the experimentalist the spectrophotometer, the Lummer-Brodhun photometer (1889) and Rood's flicker photometer (1893, 1899) should be mentioned.

Fluorescence, though ingeniously treated by Herschel (1845, 1853) and Brewster (1846, et seq.), was virtually created in its philosophical aspects by Stokes in his great papers (1852, et seq.) on the subject. In recent years Lommel (1877) made noteworthy contributions. Phosphorescence has engaged the attention of E. Becquerel (1859), among others.

The laws of photochemistry are in large measure due to Bunsen and Roscoe (1857, 1862). The practical development of photography from its beginnings with Daguerre (1829, 1838) and Niépce and Fox-Talbot (1839), to its final improvement by Maddox (1871) with the introduction of the dry plate, is familiar to all. Vogel's (1873) discovery of appropriate sensitizers for different colors has added new resources to the already invaluable application of photography to spectroscopy.

INTERFERENCE.

The colors of thin plates treated successively by Boyle (1663), Hooke (1665), and more particularly by Newton (1672, 'Optiks,' 1704), became in the hands of Young (1802) the means of framing an adequate theory of light. Young also discovered the colors of mixed plates and was cognizant of loss of half a wave-length on reflection from the denser medium. Fresnel (1815) gave an independent explanation of Newton's colors in terms of interference, devising for further evidence, his double mirrors (1816), his biprism (1819) and eventually the triple mirror (1820). Billet's plates and split lens (1858) belong to the same classical order, as do also Lloyd's (1837) and Haidinger's (1849) interferences. Brewster's (1817) observation of interference in case of thick plates culminated in the hands of Jamin (1856, 1857) in the useful interferometer. The scope of this apparatus was immensely advanced by the famous device of Michelson (1881, 1882), which has now become a fundamental instrument of research. Michelson's determination of the length of the meter in terms of the wave-length of light with astounding accuracy is a mere example of its accomplishments.

Wiener (1890) in his discovery of the stationary light wave introduced an entirely new interference phenomenon. The method was successfully applied to color

photography by Lippmann (1891, 1892), showing that the electric and not the magnetic vector is photographically active.

The theory of interferences from a broader point of view, and including the occurrence of multiple reflections, was successively perfected by Poisson (1823), Fresnel (1823), Airy (1831). It has recently been further advanced by Feussner (1880, et seq.), Sohncke and Wangerin (1881, 1883), Rayleigh (1889) and others. The interferences along a caustic were treated by Airy (1836), but the endeavor to reconstruct geometric optics on a diffraction basis has as yet only succeeded in certain important instances, as already mentioned.

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(*To be continued.*)

## *SCIENTIFIC BOOKS.*

*Species and Varieties, their Origin by Mutation.* By HUGO DE VRIES; edited by DANIEL TREMBLY MACDOUGAL. Chicago, The Open Court Publishing Co.

De Vries's great work 'Die Mutationstheorie' marks an epoch in biology as truly as did Darwin's 'Origin of Species.' The revolution that it is working is less complete, perhaps, because there has remained no such important doctrine as that of continuity to be established. But there was need of a revolution in our method of attacking the problems of evolution. Ever since Darwin's time most biologists have been content to *discuss* and argue on the *modus operandi* of evolution. The data collected by Darwin have been quoted like scriptural texts to prove the truth of the most opposed doctrines. We have seen biologists divided into opposing camps in defense of various isms, but of the collection of new data and, above all, of experimentation we have had little. The great service of de Vries's work is that, being founded on experimentation, it challenges to experimentation as the only judge of its merits. It will attain its highest usefulness only if it creates a widespread stimulus to the experimental investigation of evolution.

To be read, nowadays, a book must be brief. Much of the success of the 'Origin of Species' was due to the mass of material which was left out. The very bulkiness of de Vries's original work must prevent its being read as widely as it deserves. There was needed a briefer presentation of de Vries's views and one in English, and this need has fortunately been filled by de Vries himself in the work now under review. This book should be read with care by every biologist; the brief synopsis of its contents which alone is possible here can in no wise make such a reading unnecessary.

After an introductory chapter, the fundamental distinction between elementary species and varieties is discussed. Elementary species are forms that are distinct in several characters from their close allies and breed true. They are thought to have arisen from their parent form in a progressive way, *i. e.*, by the addition of a new characteristic. In this they are distinguished from retrograde varieties on the one hand and mere fluctuations of characters on the other.

The subject of retrograde varieties (constituting the third section of the book) assumes great importance in de Vries's system. They are varieties in the new (restricted) sense. They differ from the parent species usually in the absence of some single character; for example, the white flower variety of a plant or the hairless form of an ordinarily hirsute species. The eliminated characters are of a few, definite, constantly recurring kinds. In this respect varieties differ from elementary species whose differential characters are most varied. Moreover, varieties are subordinate to some elementary species, whereas elementary species are coordinate.

In self-fertilization varieties behave in a characteristic way. They are frequently constant. Even varieties that are intermediate between the parent species and other varieties may be as stable as the latter. Indeed, we know that certain garden varieties have been bred in their present form for two or three centuries. Such varieties may, however,

sometimes even, though rarely, revert to the ancestral form. When varieties are crossed with the ancestral species the characters of the species are dominant in the hybrids, so that the hybrid appears like the species. De Vries finds, accordingly, that many cases of apparent reversion, or atavism, in the offspring of a variety of plant are due to the accidental cross pollination with the ancestral species; the 'reverted' forms are really hybrids. This phenomenon is called by de Vries 'vicinism' —the false atavism being due to the presence of the species in the vicinity. In addition to this false atavism there can be distinguished a true one. For, although in retrograde varieties the quality that has dropped out *may* become wholly lost, it may, on the other hand, be merely latent and may reappear, usually suddenly, in some individual. At this point de Vries introduces the idea of positive varieties as opposed to negative ones. These are characterized by the addition of a quality which had been latent. (The addition of a *new* quality is, it will be recalled, in de Vries's scheme, the origin of an elementary species. But will it not be often impossible to say whether a new appearing quality is truly new or old?)

In cross-breeding the contrast between varieties and species still holds. When a new species, which is characterized by a new quality, is bred to the parent form, its germ cell bears a unit-character of which the parent species offers no representative with which it may be mated in the conjugation of the sex cells. This sort of cross is called a 'unisexual' cross (unbalanced or unsymmetrical cross would have been less ambiguous). Varieties, on the other hand, have the same characters as the parent species, only one of them is latent. This latency of the characteristic does not prevent its union with the corresponding patent characteristic of the parent species. The offspring of a unisexual cross are apt to have the various characters of one or the other parent intact, fully developed, side by side. These first generation hybrids are all of the same type; in general aspect they are intermediate between the two species and this intermediacy persists when the hybrids are inbred. In the so-called bisexual crosses, on the other hand, the first hybrid generation is said to resemble the parent species. When such hybrids are inbred a segregation of the various characters in different individuals appears. This segregation occurs in accordance with Mendel's law, and that law is applicable only to bisexual (balanced) crosses.

The fourth section treats of 'ever-sporting' varieties and is the most novel and suggestive in the book. It is essentially experimental, yet one feels that the results gained are tentative. Ever-sporting varieties are defined as 'forms that are regularly propagated by seed, are of pure and not hybrid origin, but which sport in nearly every generation.' Of such varieties two types are recognized: 'poor' races or 'half' races, and 'rich' races or 'middle' races. In the former a sport transmits its peculiarity to only a small percentage —one per cent. to three per cent.—of its progeny. In the latter a transmission to twenty-five per cent. to fifty per cent. of the offspring may occur. However, the two sorts of races are not so sharply differentiated as these figures would indicate, but naming the extremes will accentuate the fact of variability in the transmissibility of sports, in plants. The same thing is found in man. Polydactylism is in some families strongly transmitted, in others less strongly, in others almost not at all. De Vries was unable to establish a race of five-leaved crimson clover, whereas he quickly got a race of five-leaved red clover. Monstrosities behave like other variations, showing both poor and rich races. In the further development of the subject de Vries is led to explain cases of functional adaptation in plants on the ground that two types are always present in species showing these adaptations, and that 'during their juvenile stage a decision is taken in one direction or the other.' He even goes so far as to ascribe the difference in height of some plants, according as they occur in rich or poor soil to a dimorphic tendency toward, one or the other stature. This conclusion requires statistical proof before it will be generally accepted.

The fifth section is headed 'Mutations' and is, we think, the most powerful in the book. The author tells in two chapters of his early attempts to produce races having certain abnormalities—a toad-flax with peloric flowers (*i. e.,* having radial instead of bilateral symmetry) and a double daisy out of a single one. He tells the story of his discovery of the mutating evening primrose and the way it produced new varieties and species in his garden. These new forms, *when self-fertilized,* reproduced themselves in a high percentage of cases. His experience with these mutating plants led him to formulate seven laws as follows: (1) New elementary species appear suddenly, without intermediate steps; (2) they spring laterally from the main stem (not replacing it); (3) they attain their full constancy at once; (4) some of the new strains are elementary species, others are to be regarded as varieties; (5) the same new species are produced in a large number of individuals; (6) mutations undergo fluctuating variation, but the latter is not evolution and (7) mutations take place in nearly all directions.

An apparent difficulty to accepting mutations as the sole source of new species is their rarity. An investigation of the literature, however, convinces de Vries that there is a number of records of species and varieties arising by mutation and in horticulture mutating strains play an important part. In the lecture on systematic atavism the author shows that many mutations are repetitions of an ancestral condition that has lain latent (by the author's previous definition the coming into activity of latent characters is the production of positive varieties); and in the illuminating lecture on taxonomic anomalies he cites numerous wild species that are distinguished by characteristics that appear to be sports and have probably arisen *per saltum.*

In his lecture on periodic mutation de Vries sets forth the theory that in species periods of rest or stability alternate with periods of mutation. If ever we can produce the mutating period at will then we can hasten the course of evolution. De Vries concludes that, despite the long periods elapsing between successive mutation periods in any species the theory demands less time than that of selection of infinitesimal variations and so fits in better with the newer conclusions of physicists who are tending to shorten the probable age of the earth.

The final section of the book is devoted to 'Fluctuations.' It contains a keen argument against the importance for evolution of the selection of minute variations. After discussing the general laws of fluctuation as enunciated by Quetelet and Galton (and warning biologists against the use of ultra-biometric methods whose biological significance is uncertain) de Vries states that fluctuations take place in two directions only; they are either plus or minus. Mutations, on the other hand, are going on in 'all directions.' The cause of fluctuating variability is variation in nourishment. (This can hardly be true of the rays of *Pecten,* whose number is independent of size and is fixed a few hours after hatching.)

Although new species may not be produced by the selection of fluctuating characters, it is recognized that such selection may be of great importance in improving the quality of any characteristic; particularly when the improvement can be propagated by asexual methods as (in plants) by cuttings. The true method for the breeder of perennials is indeed to combine the preservation of sports, the selection of the best variants, and hybridizing. In the case of annuals it will be found that improvement by selection is impossible beyond a certain point and constant attention is needed to maintain any advance made. Indeed, it is just this difficulty of maintaining an advantage that rules out selection inside the species as of importance in nature.

The foregoing is a summary of de Vries's argument. Its force is sufficiently proved by the widespread acceptation it has gained and by the stimulus it has already given to experimental work.

As to the correctness of de Vries's conclusions the future alone can give the final decision—doubtless in some points of detail they will have to be modified. The main truth of the vast importance of mutations in the origin of species can no longer be ques-

tioned. The reviewer is convinced that as good an argument might be made from the zoological side as de Vries has made from the botanical. Undoubtedly many, if not most, of the characteristics of the races of domesticated animals and probably of feral species have arisen by mutation. Take, for example, poultry. The qualities that differentiate them are of the order of mutations—feathered feet, rose comb, elongated tail, taillessness, silky feathers, frizzled feathers, cerebral hernia, polydactyl feet, albinism and many others. All the evidence we have goes to show that these have arisen suddenly, and none of them is halved in cross-breeding. Various wild birds show these same qualities and we must conclude that in wild species also these characteristics have arisen suddenly. Thus we have various wild birds with crests like the Polish fowl (*i. e.,* the umbrella bird, *Cephalopterus*); there are 'cross bills,' showing an abnormality not uncommon among poultry; there is a syndactyl species of monkey; and there are hairless species of mammals. The long tailed condition of certain Japanese fowl is exactly duplicated in the widow-bird (*Chera*). There is hardly a sport not actually prejudicial to the well being of animals which is not realized in some species.

On the other hand, it is certainly true for zoology that many species are based chiefly on 'more' or 'less' of a certain character than an allied species. Further, since animals have a more definite form than plants, and one less modified by variations in environment the fact of geographic variation is a striking one. Now in geographic variation the forms of adjacent localities are distinguished by differences of the order of fluctuating variants; the mode being different in each place; yet the differences between remote localities are of the order of mutations. Geographic variation has been repeatedly observed among birds, fishes, insects and mollusca. It is, of course, possible that the absence of discontinuity in the species may be due to hybridization with blending of characteristics, but blending of characteristics is not so common among hybrids as to justify, offhand, such an explanation. That there is evidence of evolution without mutation can not be denied.

The distinction between species and varieties is clearly expressed by de Vries, but it is doubtful if it will be of wide service because of the difficulty of distinguishing between a 'new' character and an 'atavism.' De Vries admits (p. 564) 'It is often difficult to decide whether a given form belongs to one or another of these two groups.' We look with interest to the experimental testing of de Vries's distinction in animals.

As to the literary qualities of the book, one has first to praise the general method of exposition. It is quite a model. Apart from an occasional non-idiomatic phrase or inapt word the diction is good; but much of this success is of course due to Dr. MacDougal's careful editing. It is unfortunate that the proof reading has been rather carelessly done and that commas are so atrociously misplaced as often to obscure the sense. Otherwise the publishers have done their part well. The broad margins leave plenty of room for the reader's remarks and memoranda which so suggestive a book tends to call forth in great number.

De Vries's book is one to read and reread and then to act upon. We would not wish it less clear cut in its presentation, for then it might merely amuse. As it is it gives a stimulus to the experimental testing of his broad generalizations and iconoclastic conclusions.

C. B. Davenport.

*Theoretical Chemistry from the Standpoint of Avogadra's Rule and Thermodynamics.* By Professor Walter Nernst, Ph.D., of the University of Göttingen. Revised in accordance with the Fourth German edition. Translated into English by Robert A. Lehfeldt. London and New York, Macmillan and Company, Limited. 1904. Pp. 771.

The appearance of the fourth edition of this valuable treatise will be welcomed by all advanced workers in the field of physical chemistry. The general character of this work is too well known to call for special comment. It is distinctively an advanced work, and adapted only to those who have already a good

general knowledge of the elements of physical chemistry.

It is an unfortunate beginner into whose innocent hands such a book is placed, and this leads to a few words in reference to this phase of the subject of teaching science. It is a fair question to ask whether the error is not frequently made by over-zealous teachers, of placing works that are too advanced in the hands of their pupils. The reviewer recalls having heard a teacher of organic chemistry announce rather boastfully that his class of beginners in organic chemistry was given Richter's book, and made to master its entire contents, *i. e.*, master it from the standpoint of examination.

This was only a little more unfortunate than the placing of Ostwald's inorganic chemistry in the possession of those who were just beginning the study of general chemistry. The result in both cases would be the same, of course, inevitable failure.

A similar result would be secured by beginning the study of physical chemistry with the book under review.

A few words must be added in reference to the English translation. The translation of the first edition of this book into English, as is well-known, left much to be desired. It is not too much to say that it was inadequate and unsatisfactory. It was with some feeling of relief that the new translation was greeted. It seemed that this admirable book would now be rendered into satisfactory English. It is deeply to be regretted that the examination of the translation showed that it did not fulfil this expectation. The translator states in his own preface that 'The bulk of the old text, however, remains as it was.' This is most disappointing.

If we examine the translation page by page, we shall find so many glaring violations of good, clear, idiomatic English that we soon become disheartened. These reasons alone lead us to advise those who would work through the book to use the original German; and this raises the further question, whether it is even desirable to translate such an advanced work from the German into English? Any one who can use this book with profit can, or at least should be able to read German with ease. Is it not catering to a wrong principle to make such a work accessible to those who *must master German*, if they would follow scientific thought to any depth, to say nothing of making contributions to scientific knowledge? Every one will answer this question for himself.

In criticizing the translation adversely, it must, however, not be forgotten that to secure even this result involved an enormous amount of drudgery on the part of the translator, which will be appreciated by every one who has translated even a small book.

HARRY C. JONES.

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## SCIENTIFIC JOURNALS AND ARTICLES.

THE contents of *The American Journal of Anatomy* for September are as follows:

FRANKLIN P. MALL: 'On the Angle of the Elbow.'

E. LINDON MELLUS: 'A Study of the Location and Arrangement of the Giant Cells in the Cortex of the Right Hemisphere of the Bonnet Monkey (*Macacus Sinicus*).'

SUSANNA PHELPS GAGE: 'A Three Weeks' Human Embryo, with Especial Reference to the Brain and the Nephric System.'

WILLIAM SNOW MILLER: 'The Blood and Lymph Vessels of the Lung of *Necturus maculatus*.'

FRANK A. STROMSTEN: 'A Contribution to the Anatomy and Development of the Venous System of *Chelonia*.'

*The Journal of Nervous and Mental Diseases* for August opens with a study of clinical and post-mortem records bearing on the operability of brain tumors and their symptomatology, by Drs. G. L. Walton and W. E. Paul. Following this, Dr. S. D. Ludlum reports an experimental study on the regeneration of the peripheral nerves; and the presidential address delivered by Dr. Spiller before the American Neurological Association, on the importance in clinical diagnosis of paralysis of associated movements of the eyeballs, especially of upward and downward movements, is concluded in this number. It is extensively illustrated and elucidated by tables. The leading article in the September issue is by

Dr. Theodore A. Hoch, on a case of acute anterior poliomyelitis in a youth, sixteen years old, who died in thirteen weeks after the onset of the disease. The clinical and post-mortem records of the case are given, and the microscopical examination is extensively illustrated. The article is to be continued. Following this, Dr. Paul Masoin, physician at the colony of Gheel, Belgium, reports and briefly discusses five cases of epileptiform attacks occurring in the course of dementia præcox among patients at the colony, comparing them with the other motor exteriorations of hebephreno catatonic subjects. Dr. Guy Hinsdale next presents the history of a remarkable case of paraplegia from fracture of the first, second and third dorsal vertebræ. The patient suffered seven other fractures in the accident, an explosion. A laminectomy was performed, removing the arches of the first, second, third and a part of the fourth dorsal vertebræ. Three years after the accident the patient is able to turn herself in bed, and to walk with assistance. Dr. M. A. Bliss reports a case of small round cell sarcoma of the spinal column, and Dr. G. L. Walton one of family atrophy of the peroneal type.

## *SPECIAL ARTICLES.*

### SKULL AND SKELETON OF THE SAUROPODOUS DINOSAURS, MOROSAURUS AND BRONTOSAURUS.

#### 1. *Skull of Morosaurus.*

One of the most fortunate discoveries resulting from the American Museum excavations in the Bone Cabin Quarry deposits, in the Wyoming Jurassic, was the skull of *Morosaurus*. Hitherto our knowledge of the skull of the Sauropoda has been limited to the skull of *Diplodocus* and the posterior portion of the cranium of one specimen of *Morosaurus*, both described by Marsh.

The present specimen (Amer. Mus., No. 467) was traced by Dr. W. D. Matthew from a series of crushed cervical vertebræ. It was found in an extremely crushed condition and was restored with great skill and care by Mr. Adam Hermann, the preparator of the museum. In the region of the occiput some aid was gained from the specimen described by Marsh and from the posterior portion of another cranium also found in the Bone Cabin Quarry.

All three specimens exhibit a well-defined *parietal foramen* at the junction of the parietals, frontals and supraoccipitals. This foramen is smoothly lined with bone and leads directly down into the cerebral cavity. It is thus highly probable that it lodged a large pineal eye, an organ the existence of which was left problematical by Marsh.[1] In Marsh's drawing the parietal opening is indicated rather as a fontanelle than as a foramen.

The skull of *Morosaurus* differs from that of *Diplodocus* principally in the highly convex forehead or antorbital region, which is undoubtedly correlated with the difference in character of the great cropping teeth, which contrast widely with the slender, pencil-like teeth of *Diplodocus*. This skull shows these teeth in different stages of wear and of shedding or succession. Above, there are four premaxillary and eight maxillary teeth, decreasing in size as they extend toward the back of the jaw. From twelve to thirteen mandibular teeth are preserved. The deep, massive proportions of the premaxillaries, maxillaries and mandibular rami are also mechanically correlated with the insertion and powerful functions of these large teeth. It is evident, however, that the animal had no power of masticating its food, and that these anterior teeth served simply for prehensile purposes.

The anterior narial openings are very large and face forward and obliquely upward, rather than more directly upward, as in *Diplodocus*. The antorbital openings are correspondingly reduced. As restored, the orbits are enormous, but there is considerable deficiency of bone in the surrounding parts, so that the contours are not quite certain. From the superior aspect of the skull it is evident that both frontals and nasals were much longer than in *Diplodocus*, the latter bones sending forward median

[1] "There is no true pineal foramen, but in the skull here figured (Pl. II.) there is the small unossified tract mentioned above. In one specimen of *Morosaurus* a similar opening has been observed, but in other Sauropoda the parietal bones, even if thin, are complete."

bars uniting with the slender premaxillary processes. A striking feature is the large parietal foramen opening directly into the brain case, as above described. It is noteworthy that the occiput or back part of the skull has practically the same composition as that of the carnivorous dinosaurs, namely: (1) supraoccipitals bounding the parietal foramen posteriorly (this foramen is, however, absent in the carnivorous dinosaurs); (2) lateral parietal plates which hardly enter into the top of the cranial roof except to bound the parietal foramina at the sides; (3) the squamosals forming together with the paroccipital processes the infralateral portions of the occiput; (4) occipital condyles composed exclusively of the basioccipitals.

Correlated with the muscular insertions for the motions of the powerful neck we find two very powerful processes extending down from the basisphenoidal region, presenting a wide contrast to the comparatively slender processes observed in *Diplodocus*. The quadrates and pterygoids have substantially the same shape as in *Diplodocus;* the other bones of palate are not preserved. Of the bones of the jaw the dentaries, coronoids, articulars and angulars are well preserved, as shown in the drawing. The coronoids have a considerable upward extension, but nothing to compare with that seen in the Predentata since it is not necessary to provide for the insertion of muscles of mastication.

It is this skull which was mainly used in the mounted skeleton of *Brontosaurus* in the museum; only the anterior part of the skull of this animal being known.

2. *Mounted Skeleton of Brontosaurus.*

The mounting of *Brontosaurus* has occupied the museum staff more or less continuously since the discovery of the skeleton by Mr. Granger and Mr. Grant, of the American Museum expedition, in 1897. In 1898 and 1899 the excavation was completed, and a little more than two thirds of the entire skeleton was recovered. The chief missing parts are the skull, the three anterior cervicals, the fore limbs of both sides from the shoulder down, the upper portions of the sacrum, the hind limb of one side, and the terminal portion of the tail. The restoration of the skull is largely conjectural from that of *Morosaurus* above described, and the missing parts of the limbs are restored from the famous specimen in the Yale Museum, the type of Marsh's *Brontosaurus excelsus*. The terminal portion of the tail is completed from another individual in the American Museum of Natural History.

The special features of the skeleton are its large size, the absence of crushing of the bones, and the completeness of the ribs. The mounting represents not only prolonged work of difficult restoration under the supervision of the head preparator, Mr. Hermann, but very careful anatomical studies, in which Messrs. Granger, Matthew and Gidley materially assisted the writer. Messrs. Granger and Matthew especially made a complete restoration of the muscles of the shoulder girdle and fore limb prior to the placing of these elements, which was an extremely difficult matter. The manus represents the single-clawed condition, resulting from comparison with the feet of many Sauropoda. The chief measurements of the skeleton are:

| | Ft. | In. |
|---|---|---|
| Length over all, from head to tip of tail | 66 | 8 |
| Length of vertebral column | 64 | 4 |
| Length of neck | 16 | 10 |
| Length of tail | 31 | 4 |
| Length of longest rib | 6 | 9 |
| Length of hind limb including foot | 10 | 7 |
| Length of fore limb including foot | 8 | 6 |
| Depth of body from lower end of pubis to top of posterior dorsal spine | 8 | 7 |
| Length of head as restored | 2 | 4 |

It is interesting to compare these measurements with those of a fully grown 'sulphur bottom' whale, carefully measured by Mr. F. A. Lucas, and reproduced at the St. Louis Exposition. This animal, a male, measured 74 feet, 8 inches, from the notch of the flukes to the tip of the nose. The approximate weight of the bones was 17,920 pounds. The entire animal was estimated at not far from 63 tons. We observe that while the body of the whale

is longer than that of *Brontosaurus,* the absence of limbs in the whale would reduce the water displacement and weight.

Several new features are brought out in relation to the proportions of *Brontosaurus.* While a number of terminal vertebræ are undoubtedly missing, the tail is less elongate and massive than was supposed by the writer at one time. There is no evidence that it served for the support of the body, nor was the fin development for propulsion in water so great as in *Diplodocus.* A second point of interest is that the sacrum, while the center for motion, was not certainly the highest point in the body, as at one time supposed by the writer. The center of the vertebræ arch upward in front of the sacrum, and while the neural spines rapidly subside, the highest point appears to have been about the middle of the back; unless, indeed, the fore limbs were very much more flexed than appear in the present mount.

There is still room for wide differences of opinion as regards the habits and means of locomotion of these gigantic animals. Some hold the opinion that the limbs were far more flexed at the knee and elbow than they are in the present mount. that on land at least the animal had rather the attitude of the alligator, and that only while submerged beneath the water were the limbs straightened for the purposes of walking along the bottom, the claws serving to keep the feet from slipping in the mud.

H. F. O.

### THE DRUMMING OF THE DRUM-FISHES (SCIÆNIDÆ).

It is rather remarkable that so common a function as the drumming of fishes should have remained so long misunderstood; that so much speculation should have been indulged in regarding a phenomenon so easily investigated in most parts of the world; and that a conspicuous specialized drumming muscle should have been either overlooked or ignored by ichthyologists.

For several years, as opportunity was afforded, I have been studying the peculiar drumming sounds made by those fishes in which this function is so strikingly developed that it has determined the family name, the inquiries being in continuation of some observations and experiments on the squeteague (*Cynoscion regalis*) carried on by Professor R. W. Tower, at Woods Hole, in 1901 and 1902, and noted by me in the Report of the U. S. Fish Commissioner for 1902 (page 137).

The diverse notions prevailing among modern writers on fishes may be seen from the following quotations from a few standard works.

Günther, in 'An Introduction to the Study of Fishes' (1880), makes only a single reference to drumming, and that a highly edifying one in connection with *Pogonias cromis:*

> These drumming sounds are frequently noticed by persons in vessels lying at anchor on the coasts of the United States. It is still a matter of uncertainty by what means the drum produces the sounds. Some naturalists believe that it is caused by the clapping together of the pharyngeal teeth, which are very large molar teeth. However, if it be true that the sounds are accompanied by a tremulous motion of the vessel, it seems more probable that they are produced by the fishes beating their tails against the bottom of the vessel in order to get rid of the parasites with which that part of their body is infested.

Jordan and Evermann, in their admirable 'American Food and Game Fishes' (1902), reassert what was stated in their 'Fishes of North and Middle America' (1898), namely, that the peculiar noise is 'supposed to be produced by forcing air from the air-bladder into one of the lateral horns.'

Boulenger, in the section on fishes in volume VII. of the Cambridge Natural History[1] (1904), discusses 'sound-producing organs' at some length, but appears to be unaware of the special mechanism existing in the drum-fishes. He cites several ways in which sounds are produced through the agency of muscles connected with the air-bladder, and copies from Sörensen[2] a diagram of the air-bladder and 'musculo-tendinous extensions from muscles of the body-wall' of a croaker (*Micropogon*

[1] Reviewed by Dr. Theodore Gill in SCIENCE, April 28, 1905.

[2] *Journal of Anatomy and Physiology,* Vol. XXIX., 1895.

*undulatus*) as an example of fishes in which 'the air-bladder, without possessing special muscles of its own, may, nevertheless, be partially invested by tendinous, or partly muscular and partly tendinous, extensions from the muscles of the body-wall.'

In the latest and best general work on ichthyology, Jordan's 'Guide to the Study of Fishes' (1905), this subject is but incidentally touched on, the principal reference being that 'the grunting noise made by most of the Sciænidæ in the water is at least connected with the large and divided air-bladder.'

The most satisfactory account of the drumming function is that of Sörensen in his paper 'Om Lydorganer hos Fiske' (Copenhagen, 1884), the essential parts of which in the present connection are restated in the article cited by Boulenger. Sörensen acknowledges, however, that he had examined only a single dead specimen of a single sciænid species (*Micropogon undulatus*), and it is not clear from his description that he recognized in the muscle in relation with the air-bladder a distinct organ rather than simply an offshoot of one of the abdominal muscles. It is also doubtful whether Dufossé (*Annales des Sciences Naturelles*, XIX.–XX., 1874), whom Sörensen quotes with approval, correctly interpreted the cause of this phenomenon in the drums, as this extract from Sörensen's paper will show (italics mine):

> By means of dissections [of *Sciæna aquila*] Dufossé has proved that tones can be produced by the activity of *most of the muscles*, which, coated with aponeuroses, are in immediate contact with the diverticula of the air-bladder, but that the most frequent and most intense tones are produced by the activity of those muscles, which, completely naked, are placed around the long branches of the largest diverticula. The tones may be of different pitch, in perfect accordance with their being formed in different places (and *under the influence of different muscles*).

The drumming act has been more thoroughly studied in the squeteague than in any other sciænid species; and the facts regarding it, as determined by Professor Tower, may here be repeated substantially as stated by me in 1902 (*l. c.*), but in somewhat greater detail:

1. There is in the squeteague a special drumming muscle, lying between the abdominal muscles and the peritoneum and extending the entire length of the abdomen on either side of the median line, the muscles of the two sides being united dorsally by a strong aponeurosis. The muscle is of a decided red color, in sharp contrast to the pale muscles of the abdominal parietes, and the fibers are very short, running at right angles to the long axis of the muscle.

2. The muscle, with the aponeurosis, is in close relation with the large air-bladder, and by its rapid contractions produces a drumming sound, with the aid of the tense air-bladder, which acts as a resonator. Experimentally, the removal of the air-bladder or the section of the nerves supplying the muscle abolishes the sound; if a removed air-bladder is restored to its place the drumming is resumed; and the substitution for a removed air-bladder of any hollow, thin-walled vessel of suitable size permits the resumption of drumming when the special muscle is stimulated.

3. The muscle exists only in the males, and only the males are able to make a drumming sound.

It is probable the drumming mechanism and function as existing in the squeteagues are typical of a majority of the genera of Sciænidæ; but there are some interesting variations in the limited number of genera which I have been able to examine in the field and laboratory. Thus in the croaker (*Micropogon undulatus*) the special drumming muscle is present in both male and female, and both sexes make the drumming sound; while in the so-called king-fishes or whitings (*Menticirrhus*) the drumming muscle and air-bladder are absent in both sexes and no drumming sounds are made. The seven commonest genera of drum-fishes found along the Atlantic coast may be thus classified with reference to the drumming function:

i. Drumming muscle present in both male and female, and drumming sound made by both sexes ........................ *Micropogon*.

ii. Drumming muscle present only in male, and drumming sound produced only by the male. *Pogonias, Sciænops, Cynoscion, Leiostomus, Bairdiella*.

iii. Drumming muscle absent in both male and female, and no drumming sound produced by either sex .................. *Menticirrhus.*

It has been observed in *Pogonias* and other genera that the drumming sounds are heard most frequently during the spawning season; and it is evident that this function is primarily sexual. Coexistent with the ability to make sounds there should be the ability to appreciate them; and Dr. George H. Parker's recent study of the squeteague ear, at the Woods Hole laboratory of the Bureau of Fisheries, has shown in that species a well-developed sound-perceiving organ. It is a suggestive fact that in the Sciænidæ the otoliths are exceptionally large; and as a meager contribution to this interesting subject I may mention that in *Menticirrhus* (in which no drumming sounds are produced) the otoliths are relatively smaller than in any of the other genera that have been examined.

Hugh M. Smith.
Bureau of Fisheries,
Washington, D. C.

## *PETER ARTEDI.*

On March tenth of this year occurred the bicentenary of the birth of Artedi, distinguished Swedish naturalist, founder of modern systematic ichthyology, friend and preceptor of Linnæus, and coworker with the latter in various departments of natural history. Prematurely cut short in his career, he left an imperishable legacy to science in his own writings, and in so far as he helped stimulate the activity of his more famous fellow countryman. It is little wonder that Artedi's name should be held in pious regard by nearly all students of his favorite science, and that the two-hundredth anniversary of his birth should have been commemorated by some tribute of homage.

On behalf of the Swedish Royal Academy of Science, a biographical sketch of Artedi, with an appreciation of his service as an investigator in biological science, was prepared by Professor Einar Lönnberg, of Upsala University, and has been translated into English by W. E. Harlock.[1] This is a plain and straightforward narrative, interesting and instructive, sympathetic but without pretense of eulogy; and though the mutual dependence of the two twin-stars of Swedish natural science is clearly set forth, there is no attempt to add luster to the one at the expense of the other. Brother students and pioneers, their relations are as pleasing to contemplate as those between Darwin and Wallace, and such comparisons as are drawn between them in this bicentenary memoir have every appearance of being true and fair-minded.

Many details of Artedi's life, his difficulties, devotion, temperament, methods of work and other matters not generally known are told in this brief biography. Those interested are commended to read the sketch itself. Only a word may be said here in appreciation of his ichthyological writings. The high regard professed for them by Dr. Günther and President Jordan in their popular works on 'Fishes' is well known, and it is rare that one meets with less favorable comments. Dr. Gill, however, is inclined to take a somewhat depreciatory view, since he remarks in Science (XXII., p. 140): "I can by no means assent to the estimate as to 'the extremely valuable historical and bibliographical works of Artedi.' * * * *" We hope that our learned critic will not take it amiss if we set over against his opinion the following extracts from the biography now in our hands:

> The fourth part of Artedi's 'Ichthyologia' is called 'Synonymia Nomium Piscium.' In it, as Günther truly remarks, references to all previous authors are arranged for every species, very much in the same manner as is adopted in the systematic works of the present day; these references and quotations are inserted under the diagnosis of each several species, entailing for the author a vast amount of labor, as Linnæus had occasion to find out when editing the work, for Artedi had not quite finished off the copying of them in. The laboriousness of the task becomes patent to all, when it is known that Artedi was so conscientious that he went back even to the ancient Greek and Latin writers, and endeavored to eluci-

[1] 'Peter Artedi: A Bicentenary Memoir,' by A. J. E. Lönnberg. Upsala and Stockholm, 1905, pp. 44.

date what they may have meant by their varied and diverse nomenclature and by other statements concerning certain fishes. More than 150 forms have been dealt with in that thorough-going style, the quotations under each one often exceeding a score in number. Artedi's 'Synonymia,' consequently, bears witness in its author not only to exceptional capacity for arduous toil and a deep and wide reading, but also to a rare degree of critical acumen and exactitude. For that reason the work forms a practically indispensable key to the earliest ichthyological literature (p. 40).

C. R. EASTMAN.

## *DECLARATION OF THE NATIONAL EDUCATIONAL ASSOCIATION AT THE ASBURY PARK MEETING.*

THE National Educational Association, now holding its forty-fourth annual convention in Asbury Park and Ocean Grove, and representing the teachers and friends of education throughout the country, makes the following declaration of principles:

1. The Bureau of Education continues to render invaluable service to the nation. It is the judgment of the association that the powers of the bureau should be enlarged and that liberal appropriations should be made to it by Congress in order to enable it to widen its usefulness.

2. The National Educational Association notes with approval that the qualifications demanded of teachers in the public schools, and especially in city public schools, are increasing annually, and particularly that in many localities special preparation is demanded of teachers. The idea that any one with a fair education can teach school is gradually giving way to the correct notion that teachers must make special preparation for the vocation of teaching. The higher standard demanded of teachers must lead logically to higher salaries for teachers, and constant efforts should be made by all persons interested in education to secure for teachers adequate compensation for their work.

3. The rapid establishment of township or rural high schools is one of the most gratifying evidences of the progress of education. We believe that this movement should be encouraged until the children of rural communities enjoy the benefits of public education to an extent approximating as nearly as practicable the education furnished in urban communities.

4. The association heartily approves of the efforts now being made to determine the proper place of industrial education in the public schools. We believe that the time is rapidly approaching when industrial education should be introduced into all schools and should be made to harmonize with the occupations of the community. These courses when introduced should include instruction in agricultural as well as manual training, etc. Wherever the conditions justify their establishment, schools that show the application of the branches of knowledge to practical life should be established.

5. The National Educational Association strongly recommends the increasing utilization of urban school buildings for free vacation schools and for free evening schools and lecture courses for adults, and for children who have been obliged to leave the day schools prematurely.

6. It is the duty of the state to provide for the education of every child within its borders and to see that all children obtain the rudiments of an education. The constitutional provision that all persons must contribute to the support of the public schools logically carries with it the implied provision that no persons should be permitted to defeat the purposes of the public school law by forcing their children at an early age to become breadwinners.

7. The national government should provide schools for the children of all persons living in territory under the immediate control of the government. The attention of Congress is specially directed to the need of adequate legislation to provide schools for the children of citizens of the United States living on naval reservations.

8. The association regrets the revival in some quarters of the idea that the common school is a place for teaching nothing but reading, spelling, writing and ciphering; and takes this occasion to declare that the ultimate object of popular education is to teach the children how to live righteously, healthily, and

happily, and that to accomplish this object it is essential that every school inculcate the love of truth, justice, purity, and beauty through the study of biography, history, ethics, natural history, music, drawing and manual arts.

9. The National Educational Association wishes to record its approval of the increasing appreciation among educators of the fact that the building of character is the real aim of the schools and the ultimate reason for the expenditure of millions for their maintenance. There is in the minds of the children and youth of to-day a tendency toward a disregard for constituted authority; a lack of respect for age and superior wisdom; a weak appreciation of the demands of duty; a disposition to follow pleasure and interest rather than obligation and order. This condition demands the earnest thought and action of our leaders of opinion, and places important obligations upon school authorities.

10. The National Educational Association wishes to congratulate the secondary schools and colleges of the country that are making the effort to remove the taint of professionalism that has crept into student sports. This taint can be removed only by leading students, alumni and school faculties to recognize that interschool games should be played for sportsmanship and not merely for victory.

11. The National Educational Association observes with great satisfaction the tendency of cities and towns to replace large school committees or boards, which have exercised through subcommittees executive functions, by small boards which determine general policies but entrust all executive functions to salaried experts.

12. Local taxation, supplemented by state taxation, presents the best means for the support of the public schools, and for securing that deep interest in them which is necessary to their greatest efficiency. State aid should be granted only as supplementary to local taxation, and not as a substitute for it.

13. We can not too often repeat that close, intelligent, judicious supervision is necessary for all grades of schools.

14. A free democracy can not long continue without the assistance of a system of state-supported schools administered by agents chosen by the people and responsible to the people for its ideals, its conduct and its results.

Eliphalet Oram Lyte,
*of Pennsylvania (Chairman),*
Charles J. Baxter, *of New Jersey,*
Edwin G. Cooley, *of Illinois,*
Frank B. Cooper, *of Washington,*
Charles D. McIver, *of North Carolina,*
Miss Anna Tolman Smith,
*of District of Columbia.*
Miss Harriet Emerson, *of Massachusetts,*
O. J. Kern, *of Illinois,*
Edward J. Goodwin, *of New York,*
William L. Bryan, *of Indiana.*
*Committee on Resolutions.*

## *SCIENTIFIC NOTES AND NEWS.*

The University of Cape Town conferred honorary doctorates on several members of the British Association on August 17, including the president, Professor G. W. Darwin, of Cambridge; Professor W. M. Davis, of Harvard University, and Professor Porter, of McGill University.

The Ophthalmological Congress, which held its annual meeting from August 2 to 5, awarded the Graefe Medal to Professor Hering, of Leipzig, for his work in the domain of physiological optics.

The Emperor of Austria has made Dr. Karl Toldt, professor of anatomy in the University of Vienna, a life member of the Austrian House of Lords.

Professor J. M. van't Hoff, the eminent physical chemist, has been elected a member of the Academy of Sciences at Turin.

Dr. J. Larmor, of Cambridge, will lecture on mathematical physics at Columbia University during the year 1906–7.

Professor Podwyssotzki, dean of the medical faculty of Odessa, has been appointed director of the Institute for Experimental Medicine at St. Petersburg.

Dr. N. L. Britton, director-in-chief of the New York Botanical Garden, and Mrs. Britton sailed for Bermuda on August 30, to carry out some botanical investigations, returning during the last week in September.

Professor Omori, the Japanese seismologist, has concluded his visit to India, where he has been investigating the conditions of earthquakes.

Professor Frederick Starr, of the University of Chicago, has been granted leave of absence of more than a year, which time he will spend among the savage tribes of Central Africa.

A Reuter telegram from Liverpool states that, at the request of the colonial office, the Liverpool School of Tropical Medicine has, with the consent of the university authorities, requested Professor Boyce to visit Belize, in British Honduras, to report on the sanitary measures in that colony necessary in view of the recent outbreak of yellow fever. Professor Boyce, who is now at New Orleans, will, after completing his observations of the methods employed by the Americans in combating yellow fever there, proceed to Belize. The latest mail advices from Brazil have brought news that both members of the yellow fever expedition of the Liverpool School at Manaos have been ill with yellow fever, one very seriously. The latter has now been invalided to Madeira to recuperate, but proposes to return to continue his work. The members of the expedition express the hope that they will now be immune. The medical officers of Manaos have shown them the greatest attention and kindness during their illness. The surviving members of the sleeping sickness expedition which the school sent to the Congo in August, 1903, returned to England by the steamship *Oron* on September 5.

The *Journal* of the New York Botanical Garden reports that Dr. P. A. Rydberg returned from two months' work in western Utah and Nevada, late in August. A large number of herbarium specimens were secured which will furnish much valuable material for the furtherance of his studies on the flora of the Rocky Mountains. Mr. George V. Nash has recently returned from an exploring trip to the interior of Hayti. Some regions hitherto unvisited by the botanist were reached and a large amount of preserved material, seeds and living plants were secured, together with many valuable notes on distribution. Professor F. E. Lloyd, of Teachers College, has returned from a summer of work at the Desert Laboratory of the Carnegie Institution at Tucson, Arizona. Professor Lloyd is carrying out some investigations upon the transpiration of desert plants under a grant from the Carnegie Institution.

Dr. Stephan Kruspes, emeritus professor of mathematics in the Polytechnic School at Buda Pesth, has died at the age of eighty-seven years.

Dr. Franz Reuleaux, emeritus professor of technology in the Berlin Technological Institute, died on August 20, at the age of seventy-six years.

Count de Brazza, known for his explorations in Central Africa, has died while on a special mission from the French government to that region.

Mr. J. W. Douglas, one of the editors of the *Entomologist's Monthly Magazine,* died on August 28, in his ninety-first year.

The eclipse expeditions to Spain were, on September 8, entertained at lunch by the mayor and municipality of Madrid. The toast of the day was proposed by the mayor, Señor Vincenti, and answered by Dr. Janssen, on behalf of the astronomical representatives of France, Germany, Holland, Italy, America, Russia, Spain and Great Britain.

It has been stated that a member of the Brazilian Chamber of Deputies had proposed that a prize of $2,000,000 should be offered for the discovery of a certain method of stamping out consumption. *The British Medical Journal* announces that the proposal has been approved by the Brazilian Parliament. The offer, however, is larger in scope than was at first reported, for it appears that the prize will be given to any one, native or foreign, who shall discover a certain means of prevention or cure of syphilis, or tuberculosis, or cancer. The Brazilian minister of the interior will, it is said, refer the proposal to a committee composed of a representative of the National Academy of Medicine, and four other members of kindred bodies in France, England, Germany and Italy. The Brazilian govern-

ment will regulate the meetings of the committee.

MESSRS. HOUGHTON, MIFFLIN & Co. announce that they will publish in eight volumes the proceedings of the International Congress of Arts and Science, held at St. Louis, in September, 1904. The volumes, ranging from 500 to 800 pages, have the following titles: 1. 'Philosophy and Mathematics'; 2. 'Politics, Law and Religion'; 3. 'Language, Literature and Art'; 4. 'Inorganic Science'; 5. 'Biology and Psychology'; 6. 'Medicine and Technology'; 7. 'Social Sciences'; 8. 'Education and Religion.' The addresses are printed as they were delivered, except that those in foreign languages have been translated into English. Short bibliographies will be given for each department of learning, and a very full index with references will be added.

MESSRS. CASSELL will publish this autumn 'The Zoological Society of London: a Sketch of its Foundation and Development, and the Story of its Farm, Museum, Gardens, Menagerie and Library,' by Mr. Henry Scherren, F.Z.S. The edition is to be limited to 1,000 copies.

To commemorate the meeting of the British Association in South Africa, a plan has been formulated to found a British Association medal for South African students.

THE International Surgical Society will hold its first congress at Brussels from September 18 to September 23.

THE eighth general meeting of the American Electrochemical Society was held in Bethlehem, from September 18 to 20.

THE department of zoology of Stanford University, has been presented with a large collection of the fresh-water fishes of Mexico by the Field Columbian Museum of Chicago. The collection is the work of Dr. S. E. Meek.

REUTER'S correspondent at Stockholm reports that Professor Nathorst has received a letter in which Lieutenant Bergendahl, who is a member of the Duc d'Orléans's Greenland Expedition, states that on July 27, as the expedition passed Cape Bismarck, unknown land was discovered. It appears that Cape Bismarck lies on a large island, and not on the mainland. The new land has been mapped as well as possible, and has received the name Terre de France. The expedition was unable to penetrate further north than 78° 16′ N. lat.

THE Historical Congress held at Rome in 1903 appointed a permanent international committee to organize an international gathering of those interested in the history of the natural sciences. The chairman was Professor Paul Tannery, of Paris, who died a few months ago. We learn from the *British Medical Journal* that in place of him the committee has now unanimously elected as its chairman Dr. Karl Sudhoff, who has just been appointed professor of the history of medicine in the University of Leipzig. The members of the committee are Drs. Benedikt, of Vienna; Blanchard, of Paris; Bobynin, of Moscow; Cajori, of Colorado Springs; Carpi, of Rome; Eneström, of Stockholm; Favaro, of Padua; Giacosa, of Turin; Guareschi, of Turin; Günther, of Munich; Heath, of London; Korteweg, of Amsterdam; Loria, of Genoa; Petersen, of Copenhagen; Rubio, of Zurich; Saavedra, of Madrid; Smith, of New York; Teixeira, of Oporto; and Zeuthen, of Copenhagen.

*Nature* states that at the annual meeting of the Academy of the Lincei, which was held on June 4 in the presence of the King and Queen of Italy, the president, Professor Blaserna, announced the result of the competition for the three Royal prizes founded by the late King Humbert. In the section of normal and pathological physiology, the prize is awarded to Professor Aristide Stefani, of Padua, for his published work dealing with the physiology of the heart and circulation, the non-acoustic functions of the labyrinth of the ear, and the serotherapeutic treatment of pneumonia. In the sections of archeology and of economic and social science, the judges reported that the competitors were not of sufficient merit to justify the award of the prizes. This is the first occasion on which so small a proportion of the prizes have been conferred, and it is proposed that in future the section of archeology shall embrace not only classical, but also christian and medieval archeology. Minis-

terial premiums intended to aid original work among teachers in secondary schools were awarded in the department of mathematical sciences to Professor Ciani (£50), Professor Pirondini (£38), and Professor Chini (£20). Out of the funds available from the Carpi prize, a sum of £32 was awarded to Dr. P. Enriques for a thesis on the changes brought about in absorbed chlorophyll by the action of the liver, and the relation existing between the derivatives of chlorophyll produced in the organism and the genesis of the hematic pigments. In his address the vice-president, F. d'Ovidio, discussed in general terms the question 'Art for Art's Sake,' dealing more particularly with the influence exerted on national life and character by art and literature.

THE autumn course of lectures of the New York Botanical Garden will be delivered in the lecture hall of the museum, on Saturday afternoons, at 4:30 P.M., as follows:

October 7, 'Autumn Features of Native Trees and Shrubs,' by Dr. N. L. Britton.

October 14, 'The Faculties of Plants,' by Dr. D. T. MacDougal.

October 21, 'Botanical Explorations in Hayti,' by Mr. Geo. V. Nash.

October 28, 'A Summer in the Desert,' by Professor Francis E. Lloyd.

November 4, 'The Sea-gardens of Tropical America,' by Dr. M. A. Howe.

November 11 (subject to be announced), by Dr. W. A. Murrill.

November 18, 'Fossil Plants,' by Dr. Arthur Hollick.

November 25, 'Tropical Fruits,' by Professor H. H. Rusby.

The director-in-chief and other members of the staff will be pleased to receive members and their friends at the grounds in Bronx Park, every Saturday for which lectures are announced. Opportunity will be given for inspection of museums, laboratories, library, herbaria, the public conservatories, the herbaceous collection, the hemlock forest and parts of the arboretum site.

THE bridge over the Zambesi River in Africa has been formally opened in the presence of the visiting members of the British Association. Professor Darwin made the opening speech.

THE New York *Evening Post* states that Major von Donat, the author of the well-known plan for the drainage and colonization of the Pontine Marshes, has placed before the Bavarian government a project for creating a source of electric power sufficient to run all the railways of the country. He would secure this power by damming the River Isar between Wallgau and Vorderritz, thus creating a new lake, and connecting this with the Walchensee and the Kochelsee. He has figured out that this would effect a saving of $10,000,000 a year.

CONSUL STEPHENS, of Plymouth, reports that a new return has just been issued for the first time by the British government. It is the counterpart of the alien immigration returns, and deals with the number of passengers who leave England for places out of Europe, discriminating between the British Empire and foreign countries. It appears that in the month of July, 21,000 Britons emigrated, two thirds being from England, 4,392 from Scotland, and 2,631 from Ireland. That is a reduction of 1,664 as compared with the corresponding month of last year. As regards the past seven months, British emigrants numbered about 151,000, an increase of 13,447. England contributed 98,460, Scotland 24,116, and Ireland 28,333. Of British and Scotch emigrants, rather more than one half go to British colonies, and Canada takes by far the greatest proportion of them. The Irish, however, prefer the United States, with the result that the republic gets more British people than Canada. It is claimed that the English and Scotch are far more partial to the Dominion than to the United States, and sent 55,000 emigrants there as against 2,000 Irish in the 7 months. South Africa holds the next place in popularity, and has taken nearly 13,000 Britons in the 7 months, while Australia attracted 6,325. The returns also show that 110,000 foreigners left the United Kingdom, chiefly for the United States, in the past 7 months.

CONSUL KEHL, of Stettin, writes explaining new regulations that have been issued for the admission of students to technical high schools in Prussia. He says: The students will be di-

vided into three classes—the 'regular attending students,' students for lectures only, and lecture-visitors. As regular students, without any exception, such young men will be accepted who have acquired the knowledge necessary for being admitted into any university, said knowledge to have been acquired at a German 'Gymnasium,' a German 'Oberrealschule' (a high school in which sciences as well as art and languages are taught), a Bavarian 'industrial school,' or the Saxonian Polytechnical Academy of Chemnitz. As to foreigners, the ministry of ecclesiastical affairs and public education is to decide whether their scholastic erudition is sufficient to admit them. German subjects, other than Prussian, will be admitted under the same conditions as Prussian subjects. As students admitted to hear the lectures only (*i. e.,* without privilege of being graduated by the board of examiners), young men will be admitted, not possessed of the education necessary for being admitted into a German university, but having acquired the schooling necessary for performing only one year's military service. The admission of such students is put into the hands of the rector of the technical high school. As lecture visitors such persons may be admitted to the lectures or demonstrations who are not eligible to either of the two classes just mentioned. The admission of lecture visitors will be granted by the rector, with the consent of the proper professor. There is particularly one new restriction in these regulations, viz., that all encouragements for foreigners are dropped. Setting aside the lecture visitors, only such foreigners will be admitted as are capable of complying with the German educational requirements or who are in possession of an equivalent foreign certificate of learning.

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## *UNIVERSITY AND EDUCATIONAL NEWS.*

Announcement is made of an anonymous gift to the Lebanon Valley College, Annville, Pa., of a hall of science to cost $80,000. Work on the building is to begin at once.

Mr. E. G. Bawden, London, has entrusted Mr. Edgar Speyer 'with a sum in cash and securities of about £100,000 to be applied to purposes of charity and benevolence, and for the advancement of knowledge, especially in aid of human suffering.' This sum has been apportioned for various purposes in the form of capital to be vested in trustees, and to be known in each case as the 'Bawden Fund.' The largest allotment is £16,000 to complete the sum of £200,000 required to bring about the incorporation of the University College in the University of London.

Girton College, Cambridge, has received £2,000 by the will of Miss Elizabeth A. Manning.

An imperial ukase has been issued at St. Petersburg, granting a liberal measure of autonomy to universities, pending the elaboration of permanent regulations. This is expected to ensure the opening of the universities and the resumption of the educational life of Russia, which has been at a stand still since February. The ukase places the election of rectors and deans of the universities, who have hitherto been appointed by the minister of education, in the hands of the university professors. The duty of seeing that academic life follows a normal and orderly course is entrusted by the ukase to professorial councils, to which has been confided jurisdiction over offences by students.

Dr. Chase Palmer, for some years professor of chemistry at the Central University of Kentucky, has accepted the position of professor of chemistry in the State College at Lexington, Ky., Dr. J. H. Kastle, who occupied the latter position, having recently gone to Washington as chief of the division of chemistry in the Hygienic Laboratory of the Marine Hospital Service.

Dr. Friend E. Clark, who has for two years been instructor in industrial chemistry in the Pennsylvania State College, has been appointed professor of chemistry in the Central University of Kentucky, at Danville.

Dr. J. Bendixson has been elected professor of mathematics in the University of Stockholm.

Dr. Oskar Brefeld, professor of botany at Breslau, has retired owing to failing eyesight.